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FEED VALUE OF HOG WASTES

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Summary

Hogs can effectively utilize their own manure as a source of feed when it has been converted into single cell protein by aerobic bacteria.

Growing-finishing hogs digest about 85 percent of a corn-soybean meal ration. The remainder of the nutrients plus most of the minerals are excreted. Farmers have traditionally used these wastes for fertilizing cropland, but the nutrients in manure can now be harvested for use in the feed supply.

Wastes are anaerobic as they come from the animal and remain so unless mixed with oxygen. Attempts to feed anaerobic wastes in both wet and dry forms have resulted in seriously depressed rate of gain and feed efficiency. The product of aerobic wastes which is created by oxidizing liquid manure has been fed more successfully. It replaces 60 pounds of 44 percent protein soybean meal per ton of hog ration when fed as a 3 percent dry matter liquid, and 200 pounds of soybean meal when fed as a centrifuged 9 percent dry matter material. When fed in this manner the nutrients are in the form of odorless aerobic bacteria containing about ~~50~~ 40 percent protein. Some minerals and vitamins are also captured.

Use of the liquid material is limited by the capacity of hogs to ingest water. Use of a centrifuge to concentrate the nutrients tightens the system. Problems with pathogens and undesirable residues have not yet been encountered.

Comparisons have been made of two anaerobic and three aerobic liquid waste systems for annual production of 1,500 and 5,000 hogs. Based on cost-returns balances alone the anaerobic systems with the wastes used for fertilizer are preferable to any of the aerobic systems. If an aerobic system is used, however, salvage of the nutrients for feeding reduces costs substantially.

Advantages of feeding these nutrients increase with size of operation.

Feeding of the nutrients from aerobic hog wastes offers little to most producers without a substantial change in their present facilities and size of operation. Only 8 percent of the hog producers in Illinois now have confinement facilities and only a tenth of these market more than 1,500 hogs per year. Only a part of these larger volume producers are equipped for handling hog wastes as a liquid. Nearly all now feed their hog rations in dry form.

New hog production systems are usually of substantial size and most employ slotted floor confinement units. Producers are tending to specialize in hog production and decrease emphasis on crop production. Odors from anaerobic hog wastes have resulted in many objections. Aerobic treatment of wastes minimizes odors and accomplishes comparable or increased digestion of the wastes. Hence aerobic systems equipped for collecting, processing and feeding of the nutrients contained in the oxidized material warrant strong consideration in the future.

FEED VALUE OF HOG WASTES

by Roy N. Van Arsdall and
John C. Gamble[1]

Animals by nature attempt to gain nutrients from the wastes of their own and other species. Hogs are especially prone to do so and have traditionally been raised with cattle because of their ability to salvage grain from the cattle wastes. This possibility is being reduced as modern systems of production separate animals by species and even separate them from their own wastes with slotted floors and pit storage.

The combination of high feed costs and problems of animal waste management have generated research to examine the potential of recycling of wastes into the feed supply on a scientific basis. This paper utilizes the evidence available to examine the economics of recycling hog wastes into the feed supply.

ASSUMPTIONS

Continuing research will undoubtedly uncover new facts concerning the recycling of hog wastes into the feed supply. This analysis, however, is based partly on hard facts, partly on best estimates by scientists, and the specifications that follow.

CONFINEMENT

Wastes dropped on pasture or on unprotected lots cannot be collected on a practical basis. Therefore consideration is given to the possibility of recyling only the wastes from hogs produced in total confinement. New systems and those of the larger size tend to be of this type, hence present the greatest

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1/ Agricultural Economist, Farm Production Economics Division, Economic Research Servide, U.S. Department of Agriculture, stationed at Urbana, Illinois, and Research Assistant, Department of Agricultural Economics, University of Illinois. Paper for use of the ERS Animal Waste Recycling Task Force. The authors acknowledge the generous technical assistance of B. G. Harmon, Department of Animal Science, and D. L. Day, Department of Agricultural Engineering; both of the University of Illinois.

potential for incorporation of a waste recycling system.

PARTIAL SYSTEM

The typical hog production system is farrow-to-finish and includes replacement animals, breeding herd, farrowing, nursery, growing and finishing. Hogs produce waste in each of these phases, but this analysis considers waste management and the potential of recycling it into the feed supply only for growing and finishing (hogs from 40 to 200 pounds). Most of the waste is produced in the growing-finishing phase.

WASTE CONTENT

Hogs are fed a ration of corn and fortified soybean meal according to current recommendations as to quantity and formulation.[2/] Approximately 85 percent of the nutrient value (amino acids and carbohydrates) of this ration is utilized by the hog -- 15 percent passes through in the feces. Minerals are maintained nearly in balance. These materials provide the basis for recapture of nutrients in a recycling operation.

ANAEROBIC WASTES

Waste materials in the body of a hog are anaerobic. They are anaerobic when excreted and, except for surface layers, tend to remain so unless mixed with sufficient oxygen to support the activity of aerobic organisms. Experimental work in the feeding of anaerobic wastes from hogs back to hogs has so far discovered only limited value for the product. The feeding of anaerobic wastes whether dried or wet has reduced rate of gain at least 10 percent and feed efficiency by as much or more. In work by Orr at Michigan State the feeding of dried swine feces cut average daily gain 39 percent and increased feed requirement per pound of gain 55 percent. Similar results were observed from feeding of dried

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2/ Carlisle, G. R. and H. G. Russell, Your Hog Business, Ration Suggestion, Ill. Agr. Ext. Ser. Cir. 1023, November 1970.

poultry wastes. Both of these types of wastes were anaerobic before being dried.[3] In contrast, Diggs showed sustained gains with 15 and 30 percent dried feces in the ration, but found severe reduction in feed efficiency at the higher level.[4]

Anaerobic wastes apparently lack palatability though with some of the lower levels of feeding of anaerobic wastes to hogs the consumption of feed has been maintained at levels near feed intake with a normal ration. Nevertheless there appears to be some inhibitor to feed utilization in the anaerobic waste itself. Research to date has not identified precisely why rate of gain and feed conversion are depressed by the feeding of anaerobic wastes. Since positive results have been realized from feeding of aerobic wastes, this analysis is limited to that kind of material insofar as feeding is concerned.

AEROBIC WASTES

Oxygen can be mixed with hog wastes to create an aerobic system. In this system the wastes are maintained in liquid form in a pit beneath a slotted floor building. The materials are constantly stirred and mixed with air with equipment designed for that purpose. Aerobic bacteria use the nutrients in the wastes -- urea, carbohydrate and eventually celluse -- for their own growth. A functioning oxidation system contains manure, and also aerobic bacteria which have converted hog wastes into their own bodies. It is essentially odorless. The liquid in the oxidation system, called oxidation ditch mixed liquor (ODML), contains about 3 percent dry matter which is approximately 40 percent protein. This protein, plus minerals and vitamins, is the material to be captured in a recycling operation.[5] The analysis which follows is limited to the possible use of such aerobic

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[3] Orr, D.E., Dept. of Animal Science, Mich. St. Univ. Research Rept. 148, Sept. 1971.

[4] Diggs, B.G., B. Baker, Jr., and F.G. James, Value of Pig Feces in Swine Finishing Rations, Journal of Animal Science 24:291, 1965.

[5] Harmon, B.G., D.L. Day, D.H. Baker, S.E. Curtis, and A.H. Jensen, Harvesting Nutrients from Swine Wastes, Illinois Swine Day, Univ. of Ill., March 1972.

material insofar as feeding is concerned.

CLOSED SYSTEM

Consideration of recycling the products of the oxidation system is restricted to the hogs that produce the waste. This avoids costly transportation and eliminates the possibility of transmitting disease or undesirable residues to other species of livestock or other hogs. The possibility of problems in such a closed system are considered minimal. First, the hogs will encounter no disease organisms except those currently in the environment. Second, no pathogen has yet been found that will survive for more than a short period in ODML. Third, antibiotics given to hogs are largely decomposed in the digestion process. Fourth, current recommendations call for removal of antibiotics from the rations of finishing hogs. Fifth, although encysted worm eggs survive and accumulate in ODML the hogs can and should be kept worm free with proper treatment thus preventing any contamination. Sixth, copper sulfate, arsenicals and other chemicals which render the oxidation system essentially sterile would be avoided in such a system.

FEEDING AEROBIC WASTES

Oxidation ditch mixed liquor contains enough protein to replace all of the soybean meal in the ration for finishing hogs if it could be collected and fed. Three methods of collecting, processing and feeding this material are considered. All require use of a liquid or paste feeding system which, though not presently popular with hog producers in the United States, is approximately equal in cost to dry feeding systems.

SETTLING BASIN

In this system the ODML moves from the oxidation ditch into a settling basin. Liquids are allowed to overflow into a retention basin for eventual

disposal or return to the ditch. The heavier materials settle toward the bottom of the basin and are pumped into a liquid feed mixing and distribution system. This system is not viewed with favor since a portion of the nutrients are in the liquid which overflows from the settling basin. It is not considered further in this analysis.

ODML

The simplest and least expensive method is to mix the ODML with dry feed ingredients to make a liquid feed or slop for the hogs. Used in this manner it is estimated that the ODML will provide the equivalent of 60 pounds of 44 percent soybean meal per ton of hog ration, and reduce the requirements for minerals by 15 percent and vitamins by 30 percent. Evidence indicates that A, D and E are the only vitamins that the ODML cannot replace completely.

Outside facilities include a small retention basin for overflow. Dumping of the oxidation ditch once every 3 years may be necessary.

The effectiveness of ODML used directly from the oxidation ditch is limited because it contains only 3 percent dry matter. Hogs are unable to consume enough water to utilize more of the protein content than the equivalent of 60 pounds of soybean meal per ton of ration. Were it possible to increase the dry matter to about 10 percent then practically all of the nutrients in the ODML could be moved into the hog ration. This could be done through drying, but a commercially feasible drying system has not yet been developed.

CENTRIFUGED ODML

The dry matter content of the ODML can be increased by passing it through a centrifuge. This process involves first passing the ODML through a screen to remove seed coats and hair, then centrifuging the remaining liquid, and pumping the resulting paste-like material, which is about 9 percent dry

matter, into the feed processing system (Figure 1).[6/]

The centrifuge will not capture all nutrients. Nevertheless, the salvaged material is sufficient to replace 200 pounds of 44 percent soybean meal per ton of hog ration and to reduce mineral needs by 45 percent and vitamin needs by 80 percent. The entire hog production system becomes essentially closed. Evaporation plus use of the liquid in feeding balances the oxidation ditch, even makes occasional addition of water necessary. Outside facilities can be reduced to a small catch basin to allow for emergency overflow in case of malfunction of waterers. Complete dumping of the ditch once every three years is considered adequate.

SYSTEM COMPARISONS

Data are insufficient to provide a basis for a firm analysis of the economics of the value of hogs wastes as nutrients in the feed supply. Feed replacement values previously listed are based on research in process and can only be termed "best estimates." Equipment for collecting, processing and feeding the material is in the experimental stage. The type and cost of such equipment will no doubt change if it is manufactured in quantity. Nevertheless, an economic analysis based on "best estimates" provides clues to the general magnitude of probable costs and/or benefits.

Consideration of feeding the nutrients contained in aerobically digested hog waste without regard to alternative methods of waste management would fail to recognize other alternatives open to producers. Therefore, this analysis compares feeding with other uses of liquid wastes from hogs grown and finished in confinement . Two sizes of operation are evaluated -- 1,500 and 5,000 hogs produced annually. Since multiple turnover is achieved

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6/ Holmes, L.W.J., Concentration of Proteinaceous Solids from Aerated Swine Manure, Unpublished M.S. thesis, Univ. of Illinois, 1971.

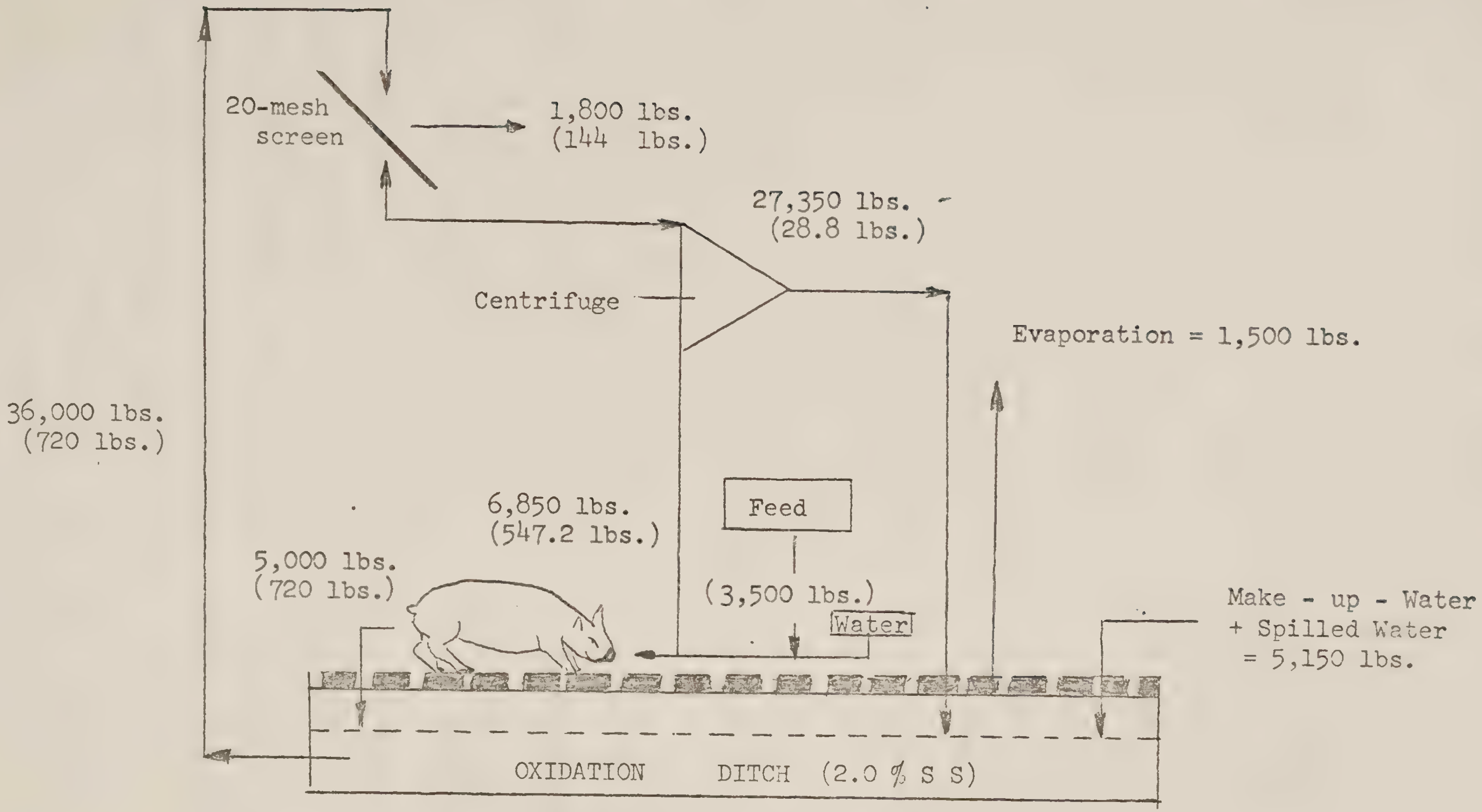

Figure 1. Flow diagram of an essentially closed-system swine ODML refeeding program for one thousand 100 pound pigs. Quantities are for one day with dry matter amounts in parentheses (model is theoretical).

the smaller operation requires a 600 head capacity building; the larger one a 2,000 head capacity building.

SYSTEMS

All systems considered are slotted-floor confinement units with pit storage for the wastes beneath the building. The systems then differ depending upon the method of handling the wastes. A description of each system follows.

Anaerobic (System A) -- A lagoon is provided for storage and decomposition of the liquid that overflows from the pit. The more concentrated portions of the waste are kept in the pit, then pumped, hauled, and spread on land when the ground is not frozen (about 8 months of the year). Farmland is assumed available to the producer and the manure provides fertility constituents to crops.

Anaerobic (System B) -- This system is the same as "A" except that the wastes are injected into the soil to minimize objectionable odors and lessen the possibility of runoff.

Aerobic (System C) -- Wastes are maintained in an aerobic state with oxidation equipment. A retention basin is provided for overflow liquid. The pit is dumped once every three years when minerals have accumulated to a high level. None of the waste is utilized for either feed or fertilizer.

Aerobic (System D) -- This system is the same as "C" except that the ODML is pumped from the oxidation ditch into a holding tank where it is continually stirred for 24 hours. Then it is pumped into a liquid feeding system. A retention basin is provided for possible overflow of the ditch. The ditch is dumped once every three years.

Aerobic (System E) -- This system is the same as "C" except that the ODML is passed through a screen to remove coarse materials, then put through a centrifuge to concentrate the nutrients which are then pumped into a liquid

feeding system. A small catch basin is provided to insure against possible over flow. The system is closed except that the pit is dumped once every 3 years.

VALUE OF WASTE

Feed Value. The gross value of the ODML and centrifuged ODML is based on the amount of soybean meal, minerals and vitamins that they will replace in 16 and 13 percent protein corn-soybean meal growing and finishing rations (Table 1). The metabolic energy in the dry matter contained in the ODML is as yet undetermined, so in this analysis the amount of corn required is assumed to be unaffected by the substitution of the oxidation ditch material for soybean meal.

Based on usual ingredient prices available to farmers who buy feeds in the quantities needed for operations of the sizes considered in this analysis the effective cost of a ton of growing or finishing ration can be reduced from $3 to $9 depending upon whether ODML or centrifuged ODML is used. Variations in the price of soybean meal will directly affect the value of the ODML used to replace it.

Anticipated savings in the cost of minerals and vitamins, while relatively unimportant in an economic sense, are indicative of values other than protein that can be recovered from hog wastes. Further, the recycling of minerals reduces their accumulation in the pit and thus decreases the need for alternate waste utilization or disposal outside of the hog facilities.

Growing and finishing one hog from 40 to 200 pounds requires about 520 pounds of feed under good management.[7/] Based on the feed ingredient prices used in this analysis the cost of this amount of feed is $12.30. Use of ODML reduces this cost by $.73; centrifuged ODML by $2.73 (Table 2).

[7/] Carlisle, G.R. and H.G. Russell, Your Hog Business, Ration Suggestions, Ill. Agr. Ext. Ser. Cir. 1023, Nov. 1970.

Table 1 . -- Estimated Impact on Feed Requirements and Ration Costs of Refeeding Aerobic Wastes to Hogs.[a]

Rations	Basic Ration Alone				Basic Ration plus ODML[b]		Basic Ration plus Centrifuged ODML[c]	
	Ingredients	Unit Cost	Amount	Cost	Amount	Cost	Amount	Cost
		($)	(lbs.)	($)	(lbs.)	($)	(lbs.)	($)
16% Protein (40-120 lbs.)	Corn	.02	1,550	31.00	1,550	31.00	1,550	31.00
	SBM (44%)	.04	400	16.00	340	13.60	200	8.00
	Additives[d]	--	50	2.00	50	1.60	50	.85
	Total	--	2,000	49.00	1,940	46.20	1,800	39.85
Ration Cost/cwt[e]	---	---	---	2.45	---	2.31	---	1.99
13% Protein (120-200 lbs.)	Corn	.02	1,710	34.20	1,710	34.20	1,710	34.20
	SBM (44%)	.04	250	10.00	190	7.60	50	2.00
	Additives[d]	---	40	1.80	40	1.45	40	.80
	Total	---	2,000	46.00	1,940	43.25	1,800	37.00
Ration Cost/Cwt[e]	---	---	---	2.30	---	2.16	---	1.85

a/ Based on Illinois Agr. Ext. Ser. Cir. 1023 for basic rations and preliminary results of research by B.G. Harmon, and associates, Dept. of An. Sc., Univ. of Illinois.

b/ Oxidation ditch mixed liquor (ODML) containing 3 percent dry matter.

c/ Centrifuged ODML containing 9 percent dry matter.

d/ Estimated cost of fortifying ingredients including minerals and vitamins but excluding antibiotics. Potential contribution of ODML to needs for minerals and vitamins are estimated.

e/ Each ration is assumed to be the equivalent in performance of the 2,000 lb. basic ration.

Table 2. -- Estimated Impact on Cost of Feed for Growing a Pig from 40 to 200 Pounds by Refeeding Aerobic Wastes.

Gain Period	Ration Number	Amount of Feed[a]	Cost[b] Basic Ration Cwt.	Basic Ration Total	Basic + ODML Cwt.	Basic + ODML Total	Basic + Centrifuged ODML Cwt.	Basic + Centrifuged ODML Total
	(% Protein)	(lbs.)	($)	($)	($)	($)	($)	($)
40 - 120 lbs.	16	225	2.45	5.51	2.31	5.20	1.99	4.48
120 - 200 lbs.	13	295	2.30	6.79	2.16	6.37	1.85	5.46
Total	--	520	--	12.30	--	11.57	--	9.94
Reduction in Feed Cost per Head	--	--	--	--	--	.73	--	2.36

a/ Pounds actually fed via the basic ration or from a combination of basic ration plus ODML. The reduction in cost per hundred weight compensates for the supplement replaced by the ODML.

b/ Unit costs are developed in Table 1 of this report.

Total feed required to raise a pig from farrowing to market weight, including his share of production and maintenance of the breeding herd, amount to 732 pounds. Thus 212 pounds of feed or nearly one-third of the total requirement goes into wastes that are not recycled into the feeding program in this analysis. They are assumed to be disposed of in an oxidation system or dropped on pasture yielding no value in either case. Acceptable means for utilizing these additional wastes would add to the values already estimated.

Fertilizer. The plant nutrient content of animal manures has long been a debatable subject, especially with respect to the availability of the major nutrients and the existence of trace elements. It is certain, however, that nitrogen, phosphorus and potassium are the most important constituents. The value of anaerobic hog wastes for growing crops is therefore based on the amount of these elements that the waste contains at the price of the same elements in commercial mineral fertilizer, adjusted for losses in application.

The rate of recovery of N, P_2O_5, and K_2O from anaerobic wastes depends on many factors.[8/] For this analysis it is assumed that 67 percent of the P_2O_5 and K_2O are as effectively utilized as the same elements from commercial fertilizer whether applied to the land surface of injected into the soil. Two-thirds of the nitrogen is also assumed collected from the pit, but it is only 40 percent effective when surface applied and 70 percent effective when injected into the soil.

On this basis 2.9 pound of P_2O_5 and 2.4 pounds of K_2O are available for crops from each hog raised from 40 to 200 pounds. The nitrogen recovered is approximately 2.2 pounds when applied to the surface of the land and 3.8 pounds when injected into the soil. Prices of 8.7¢, 9.2¢ and 5.0¢ for N, P_2O_5,

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8/ Kesler, R.P. and R.A. Hinton, An Economic Evaluation of Liquid Manure Disposal from Confinement Finishing Hogs, Ill. Agr. Exp. Sta. Bul. 722, Dec. 1966.

and K_2O, respectively, result in a fertilizer value of $.57 per hog for surface application and $.71 for soil injection. These values for 1,500 and 5,000 hogs are expressed in Tables 3 and 4.

INVESTMENT

The most costly part of a liquid waste handling system is the slotted floor and storage pit. These facilities, minus the cost of the pit floor, plus a lagoon or retention basin are identified as investments in structures (Tables 3 and 4).[9/] Although both anaerobic and aerobic systems require pits the former must have a pit of larger capacity for storage. Equipment for the anaerobic system includes a 1,500 gallon manure tank with pump plus an injector attachment if the manure is to be injected into the soil. A tractor of approximately 50 PTO horsepower is needed to handle surface application equipment; 90 HP for soil injection.

Equipment for the aerobic systems (C, D, and E) includes one oxidation wheel for each 300 head of hogs in the building at one time. Pumps are needed in system D to move the ODML into a holding tank and then into a liquid feeding system. A stainless steel screen, holding tank, centrifuge, and two pumps comprise the equipment complement in system E.

Details of investment requirements and annual costs for structures and equipment are shown in the Appendix.

ANNUAL COSTS

The annual costs, including both fixed and operating costs, are relatively high for all of these systems, generally ranging from $2 to $5 per hog. Economies of size occur between the 1,500 and 5,000 head operations.

9/ The pit floor is equivalent to the floor in solid floor building. Hence these investments for structures reflect the added cost of constructing slotted floor buildings with pit storage instead of solid floor buildings.

Table 3. -- Estimated Initial Investment, Annual Costs, and Monetary Benefits of Selected Systems for Waste Management for Growing and Finishing 1,500 Hogs per Year in a Totally Slotted Floor Confinement Unit.

	Waste Material[a]			Investment[b]			Annual Cost[b]			Value	Net
Type	Use	Method of Processing	Method of Use	Structure	Equipment	Total	Fixed	Variable	Total	of Waste[c]	Cost[d]
				($)	($)	($)	($)	($)	($)	($)	($)
Anaerobic (A)	Fertilizer	Mix	Soil Surface	15,595	2,300	17,895	3,336	336	3,672	858	2,814
Anaerobic (B)	Fertilizer	Mix	Inject Into Soil	15,595	3,000	18,595	3,497	448	3,945	1,065	2,880
Aerobic (C)	None	None	Lagoon	15,320	3,600	18,920	3,838	1,293	5,131	0	5,131
Aerobic (D)	Feed	Pump ODML	Liquid Feeding	14,655	4,400	19,055	3,909	1,373	5,282	1,095	4,187
Aerobic (E)	Feed	Centrifuge ODML	Liquid Feeding	14,250	11,750	26,000	5,541	1,766	7,307	3,540	3,767

a/ See description of systems in text.

b/ See Appendix Tables 1-5.

c/ See text for derivation of fertilizer values and text Tables 1 and 2 for derivation of feed values.

d/ Net cost is total annual cost minus value of the waste.

Table 4. -- Estimated Initial Investment, Annual Costs and Monetary Benefits of Selected Systems for Wastes Management for Growing and Finishing 5,000 Hogs per Year in a Totally Slotted Floor Confinement Unit.

Type	Waste Material[a] Use	Waste Material[a] Method of Processing	Waste Material[a] Method of Use	Investment[b] Structure	Investment[b] Equipment	Investment[b] Total	Annual Cost[b] Fixed	Annual Cost[b] Variable	Annual Cost[b] Total	Value of Waste[c]	Net Cost[d]
				($)	($)	($)	($)	($)	($)	($)	($)
Anaerobic (A)	Fertilizer	Mix	Soil Surface	46,770	2,300	49,070	8,948	1,117	10,065	2,850	7,215
Anaerobic (B)	Fertilizer	Mix	Inject into Soil	46,770	3,000	49,770	9,109	1,491	10,600	3,550	7,050
Aerobic (C)	None	None	Lagoon	48,080	10,800	58,880	11,894	4,752	16,646	0	16,646
Aerobic (D)	Feed	Pump ODML	Liquid Feeding	46,990	12,600	59,590	12,133	4,802	16,935	3,650	13,285
Aerobic (E)	Feed	Centrifuge ODML	Liquid Feeding	46,220	33,150	79,370	16,750	5,490	22,240	11,800	10,440

a/ See description of systems in text.

b/ See Appendix Tables 1-5.

c/ See text for derivation of fertilizer values and text Tables 1 and 2 for derivation of feed values.

d/ Net cost is total annual cost minus value of the wastes.

Annual costs on a unit basis would increase dramatically if size of operation were less than 1,500 head produced annually as much of the equipment specified for this size of operation (Table 3) is of the smallest size now available. Further economies can be realized for operations larger than 5,000 head.

Annual costs are high for several reasons. First, life of equipment used in the aerobic systems was placed at 5 years. New equipment may prove to be quite durable, but oxidation equipment now in use has presented maintenance problems. Further, obsolescence seems certain to be an important factor. Second, labor has been valued at $3.00 per hour. This is well above the average farm wage rate, but methods considered in this analysis can be used only by the better managers with the larger operations. Third, power is a costly item, especially in the aerobic systems where the oxidation equipment must operate continuously on a year round basis.

NET COSTS

The magnitude of net cost (total annual cost minus the value realized from the waste) is of interest, but it is important here chiefly as a basis for comparing the 5 systems included in this analysis. Solid floor units and pasture systems of hog production also require investments and operating costs for handling wastes and they are not measured in this analysis. Significance is placed only on the difference in net cost among the 5 systems examined here.

Two different positions must be taken to get a meaningful comparison of the net cost of these systems. First is the question of whether to employ an anaerobic or an aerobic system. The second question concerns the disposition of the waste once the basic system of handling the liquid wastes has been chosen.

If adequate farmland can be controlled along with the hog operation,

and if problems of odor and runoff can be managed successfully, then it seem apparent that the anaerobic systems have much lower net costs than any of the aerobic systems. Soil injection is equal to or better than surface application on a net cost basis. Nearly all producers with pit storage beneath the house now use anaerobic systems and are gradually shifting to soil injection as opposed to surface application for better control of odor and runoff.

If on the other hand producers eventually find it necessary to employ an oxidation system, as well they may in the more densely populated parts of the country, then harvesting of the nutrients from the ODML and returning them to the feed supply is far superior to complete disposal via an oxidation system. Possible problems from production of anaerobic wastes and the relative benefits of a nutrient harvesting system for use with the aerobic materials both increase with size of operation.

APPLICABILITY

Systems of liquid waste management, whether anaerobic or aerobic, have limited applicability at present. Using Illinois as an example (Illinois is probably further advanced in terms of confinement production and size of operation than any of the other major hog producing states) a 1971 survey shows that only 8 percent of the some 50,000 producers in the state use confinement facilities (Table 5). They produce 15 percent of the hogs marketed.

This represents a substantial number of both farmers and hogs, but few of these farmers could profitably adopt the systems for harvesting nutrients from aerobic wastes as described in this paper. First, less than 10 percent of those using confinement have annual marketings exceeding 1,500 hogs per year. Costs would be quite high for those with lesser volumes. Second, a substantial portion of the confinement systems in the state are not designed

Table 5. -- Percent of Total Hogs Marketed and Percent of Total Hog Farms by Selected Size Groupings and Method of Production, Illinois, September 1970 - August 1971[a/]

Size grouping and production method	Hog farms	Hogs marketed
	(percent)	(percent)
Size grouping		
1 - 150	48	13
151 - 350	29	24
351 - 700	15	27
701 - 1500	7	24
More than 1500	1	12
Total	100	100
Production method		
Pasture only	31	24
Paved lot only	16	16
Dirt lot only	18	13
Pasture and dirt lot	14	11
Confinement only	6	11
Confinement plus other methods	2	4
Other combinations excluding confinement	13	21
Total	100	100

[a/]Preliminary data from Illinois Crop and Livestock Reporting Service.

Table 6. -- Percent of Hogs Marketed Per Year Within Selected Size Groupings by Method of Production, Illinois, September 1970 - August 1971.[a]

Method of production	Hogs marketed per year (head)											
	1-150		151-350		351-700		701-1500		More than 1500		All size groups	
	Head (000)	Percent	Head (000)	Percent	Head (000)	Percent	Head (000)	Percent	Head (000)	Percent	Head (000)	Percent
Pasture only	630	41	740	26	730	23	480	17	210	15	2,790	24
Paved lot only	180	12	560	20	800	25	260	9	40	3	1,840	16
Dirt lot only	350	23	370	13	260	8	310	11	270	19	1,560	13
Pasture and dirt lot	280	17	510	18	350	11	140	5	30	2	1,290	11
Confinement only	30	2	110	4	190	6	450	16	500	35	1,280	11
Confinement plus other methods	--	--	30	1	60	2	310	11	120	8	520	4
Other combinations excluding confinement	80	5	510	18	800	25	880	31	250	18	2,520	21
Total	1,530	100	2,830	100	3,190	100	2,830	100	1,420	100	11,800	100

[a] Preliminary data from Illinois Crop and Livestock Reporting Service Survey.

to handle liquid manure. Floors would have to be removed and pits installed. Third, those who have slotted floors and pit storage would have to make substantial alternations to prepare the raceways necessary for an oxidation system. Presently, only about 100 oxidation systems are in use in all livestock and poultry production throughout the state.

All liquid systems, and especially those that treat hog wastes aerobically, will be in an increasingly stronger position as time passes. Size of hog operations are increasing rapidly. New systems, especially those of larger size, are nearly always based on confinement facilities with slotted floors and liquid storage for manure. There is a growing tendency to specialize in hog production rather than crop-hog farming units. Further, odor from anaerobic wastes, especially at time of removal from storage and spreading, is a major cause of complaints received by farmers.

Based on the limited evidence at hand it is impossible to identify precisely the economic benefits of recycling of hog wastes into the feed supply. The potential seems strong enough, however, to warrant strong encouragement for intensive research into the technologies and economics of harvesting, processing and utilizing the nutrients produced in aerobic hog wastes.

Table 7. -- Percent of Hog Farms (Producers) Within Selected Size Groupings of Hogs Marketed Per Farm by Method of Production, Illinois, September 1970 - August 1971.[a]

Method of production	Hog farms (producers) by hogs marketed per farm											
	1-150		151-350		351-700		701-1500		more than 1500		All size groups	
	Farms	Percent	Farms	Percent	Farms	Percent	Farms	Percent	Farms	Percent	Farms	Percent
	(no.)		(no.)		(no.)		(no.)		(no.)		(no.)	
Pasture only	9,500	40	3,600	25	1,600	21	500	15	100	17	15,300	31
Paved lot only	2,600	11	3,050	21	2,000	26	350	10	*	--	8,000	16
Dirt lot only	5,950	25	2,050	14	700	9	400	11	100	17	9,200	18
Pasture and dirt lot	3,600	15	2,600	18	800	10	150	5	*	--	7,150	14
Confinement only	1,200	5	600	4	450	6	550	16	200	33	3,000	6
Confinement plus other methods	--	--	150	1	150	2	350	10	50	8	700	2
Other combinations excluding confinement	950	4	2,450	17	2,000	26	1,100	33	150	25	6,650	13
Total	23,800	100	14,500	100	7,700	100	3,400	100	600	100	50,000	100

[a] Preliminary data from Illinois Crop and Livestock Reporting Service

*Less than 25.

Appendix

Exhibit A. -- Cost Factors Used in Computing the Annual Fixed and Operating Costs for Systems A-E, as Shown in Appendix Tables 1-5, and for Feed and Fertilizer.

Item	Rate	
Depreciation		
Structures	10	percent
Field Equipment	15	percent
Inside Equipment	20	percent
Interest on Average Investment	8	percent
Taxes & Insurance on Average Investment	2	percent
Repairs (Based on New Investment)	3 - 5	percent
Electricity	$ .02	per KWH
Wage Rate	$ 3.00	per hour
Corn	.02	per lb.
Soybean Meal (44% Protein)	.04	per lb.
Nitrogen	.087	per lb.
P_2O_5	.092	per lb.
K_2O	.050	per lb.

Exhibit B. -- Investments and Annual Costs of Five Liquid Waste Management Systems for 1,500 and 5,000 Head Annual Production of Hogs from 40 to 200 Pounds.

Appendix Table 1. -- Investment and Annual Cost of a Liquid Anaerobic Waste System with Lagooning and Surface Application of Wastes.

Item	1,500 Annual Hog Marketings		5,000 Annual Hog Marketings	
	Building	Equipment	Building	Equipment
Investments				
Concrete slats	8,410	---	27,650	---
Clean-out tubes	180	---	540	---
Concrete pit side walls[a]	2,550	---	8,230	---
Concrete support columns	1,800	---	6,000	---
Lagoon[b]	2,655	---	4,350	---
Tank spreader (1,500 gal.)	---	2,300	---	2,300
Subtotal	15,595	2,300	46,770	2,300
Grand Total		17,850		49,070
Annual Costs				
Operating Costs				
Labor (pump, haul, & spread)		186		621
Tractor (oil, gas, grease)		46		151
Tractor (over-head on hourly rate)		104		345
Subtotal		336		1,117
Overhead Costs				
Buildings		2,807		8,419
Equipment		529		529
Subtotal		3,336		8,948
Grand Total		3,672		10,065

a/ Pit floor is excluded.

b/ Includes cost of overflow tubes from buildings to lagoon.

Appendix Table 2. -- Investment and Annual Cost of A Liquid Anaerobic Waste System with Lagooning and Soil Injection of Wastes.

Item	1,500 Annual Hog Marketings		5,000 Annual Hog Marketings	
	Building	Equipment	Building	Equipment
Investment				
Concrete slats	8,410	---	27,650	---
Concrete pit side walls[a]	2,550	---	8,230	---
Clean-out tubes	180	---	540	---
Concrete support columns	1,800	---	6,000	---
Lagoon[b]	2,655	---	4,350	---
Tank spreader & soil injector (1,500 gal.)	---	3,000	---	3,000
Subtotal	15,595	3,000	46,770	3,000
Grand Total		$18,595		$49,770
Annual Costs				
Operating Costs				
Labor (pump, haul, and spread)		186		621
Tractor (oil, gas, grease)		82		273
Tractor (overhead on hourly rate)		180		597
Subtotal		448		1,491
Overhead Costs				
Buildings		2,807		8,419
Equipment		690		690
Subtotal		3,497		9,109
Grand Total		$3,945		$10,600

a/ Pit floor is excluded.

b/ Includes cost of overflow tubes from buildings to lagoon.

Appendix Table 3. -- Investment and Annual Cost of A Liquid Aerobic Waste System with Wastes Disposed of in Oxidation Ditch and Lagoon.

Item	1,500 Annual Hog Marketings		5,000 Annual Hog Marketings	
	Building	Equipment	Building	Equipment
Investment				
Concrete slats	8,410	---	27,650	---
Concrete pit side walls[a]	2,185	---	7,055	---
Concrete partitions	3,250	---	10,750	---
Over flow tube to lagoon	150	---	450	---
Lagoon	1,325	---	2,175	---
Oxidation wheels ($1,800 each)	---	3,600	---	10,800
Subtotal	15,320	3,600	48,080	10,800
Grand Total		$18,920		$58,880
Annual Costs				
Operating Costs				
Electricity[b]		1,248		4,577
Waste hauling (custom)[c]		45		175
Subtotal		1,293		4,752
Overhead Costs				
Buildings		2,758		8,654
Equipment		1,080		3,240
Subtotal		3,838		11,894
Grand Total		$5,131		$16,646

a/ Pit floor is excluded.

b/ Oxidation wheels have 5 HP electric motors that operate continuously.

c/ Custom hauling to dump pit once each 3 years.

Appendix Table 4. -- Investment and Annual Cost of A Liquid Aerobic Waste System with Part of the ODML fed and the Remainder Lagooned.

Item	1,500 Head Annual Marketings		5,000 Head Annual Marketings	
	Building	Equipment	Building	Equipment
Investment				
Concrete slats	8,410	---	27,650	---
Concrete pit side walls[a]	2,185	---	7,055	---
Concrete partitions	3,250	---	10,750	---
Overflow to lagoon	150	---	450	---
Lagoon	660	---	1,085	---
Oxidation wheels ($1,800 each)	---	3,600	---	10,800
Fiberglass storage tank and mixer[b]	---	700	---	1,500
Pump	---	100	---	300
Subtotal	14,655	4,400	46,990	12,600
Grand Total		$19,055		$59,590
Annual Costs				
Operating Costs				
Electricity[c]		1,343		4,687
Waste hauling (custom)[d]		30		115
Subtotal		1,373		4,802
Overhead Costs				
Buildings		2,638		8,458
Equipment		1,271		3,675
Subtotal		3,909		12,133
Grand Total		5,282		16,935

a/ Pit floor is excluded.

b/ 1,500 and 5,000 gallon capacities.

c/ Continuous operation of 5 HP motors on oxidation wheels, stirring of ODML in storage tank, and pumping ODML.

d/ Custom hauling to dump pit once each three years.

Appendix Table 5. -- Investment and Annual Cost of a Liquid Aerobic Waste System with the ODML Centrifuged for Addition to the Hog Feed.

Item	1,500 Head Annual Marketings		5,000 Head Annual Marketings	
	Building	Equipment	Building	Equipment
Investment				
Concrete slats	8,410	---	27,650	---
Concrete pit side walls[a]	2,185	---	7,055	---
Concrete partitions	3,250	---	10,750	---
Overflow and catch basin	405	---	765	---
Oxidation wheels ($1,800 each)	---	3,600	---	10,800
Industrial stainless steel screen[b]	---	2,150	---	2,150
Pumps	---	300	---	700
Centrifuge (including wiring)[c]	---	5,000	---	18,000
Fiberglass storage tank and mixer[d]	---	700	---	1,500
Subtotal	14,250	11,750	46,220	33,150
Grand Total		26,000		79,370
Annual Costs				
Operating Costs				
Electricity (oxidation wheels)		1,248		4,577
Electricity (centrifuge and pump)		488		798
Waste hauling (custom)[e]		30		115
Subtotal		1,766		5,490
Overhead Costs				
Buildings		2,565		8,320
Equipment		2,976		8,430
Subtotal		5,541		16,750
Grand Total		7,307		22,240

a/ Pit floor is excluded.

b/ Includes $150 for equipment to dispose of screenings.

c/ Small centrifuge is powered by a 2 HP motor, has an output of 26 pounds of 9 percent drymatter material per 6 minute cycle, and operates 14 hours per day. Large centrifuge is powered by a 10 HP motor, has an output of 192 pounds of 9 percent drymatter material per 6 minute cycle, and operates 7 hours per day.

d/ 1,500 and 5,000 gallon capacities. e/ Custom hauling to dump pit each three years.

Appendix Exhibit C. -- Details of Systems for Anaerobic and Aerobic Waste Management Systems for Growing and Finishing 1,500 and 5,000 Hogs per Year.

A. 1,500 Hogs (based on 6 farrowings per year)

1. Building - 36 ft. x 146 ft., totally enclosed, completely slotted floor.
2. Capacity - 600 growing-finishing pigs at one time with 6 square feet per growing pig and 8 square feet per finishing pig. Building length is limited to 160 ft. because minimum velocity of the liquor in an oxidation ditch cannot be maintained if oxidation wheels are farther than 350 feet apart.

B. 5,000 Hogs (based on 8 farrowing per year)

1. Building - three 36 ft. x 160 ft.,totally enclosed, completely slotted floor.
2. Capacity - 2,000 growing-finishing pigs at one time with 6 and 8 square feet per head as required.

C. Building Cost Components

1. Concrete side walls for anaerobic pit - 8" x 5' @ $7/running ft.
2. Concrete side walls for aerobic pit - 8" x 4' @ $6/running ft.
3. Clean-out tubes - $30 each.
4. Support columns for floor - $25 each.
5. Earth moving for lagoon - $.60 per cubic yard.
6. Overflow tile to lagoon - $150 per building.
7. Concrete partitions for oxidation ditch - 1' x 4' @ $8/running ft.
8. Slotted concrete floor - $1.60 per square foot.

D. Labor for Waste Handling

1. Anaerobic, spread on surface - 0.29 hours per 7 pigs.
2. Anaerobic, inject into soil - 0.29 hours per 7 pigs.
3. Aerobic - combined with custom charges.